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THE CLASSIFICATION OF THE UPPER PALÆOZOIC ROCKS OF CENTRAL KANSAS.[1]

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INTRODUCTION.

RECENT studies of the geology of eastern central Kansas, [illegible] connection with the preparation of geologic maps of that region for the United States Geological Survey, have acquainted the writer with interesting facts in reference to the description and classification of the Upper Palæozoic rocks of Kansas.

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[1] Published by permission of the Director of the United States Geological Survey.

The early geologists of the state, Hawn, Swallow, Meek and Hayden engaged in a spirited controversy, not only in regard to the correlation of the geological formations of this part of the state, but also as to whom belonged the honor of first announcing the discovery of the Permian rocks in Kansas. Major Hawn stated that his first impression that the rocks in question might be of Permian age was obtained from a letter written by Mr. Meek, September 3, 1857.[1] On January 19, 1858, at the request of Meek and Hayden, a record was made at the Smithsonian Institution in which is mentioned "forms indicating Permian both in Kansas and the region of the Black Hills."[2] In determining the date of the first scientific publication of the discovery of Permian fossils in Kansas neither of these records should be considered. The first public announcement before a scientific society of the identification of Permian fossils in Kansas was made by Professor G. C. Swallow in a letter read by Professor B. F. Shumard before the St. Louis Academy of Science, on February 22, 1858.[3]

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[1] Am. Jour. Sci., 2d series, Vol. XXVI., p. 188; *ibid.*, Vol. XLIV., p. 38. Trans. Acad. Sci. St. Louis, Vol. II., p. 511.

[2] Am. Jour. Sci., 2d series, Vol. XLIV., 1867, pp. 38, 39. See *ibid.*, Vol. XXVI., 1858, p. 188, and Trans. Acad. Sci. St. Louis, Vol. II., p. 511.

[3] See Trans. Acad. Sci. St. Louis, Vol. I., pp. 111, 112. The letter, which was dated February 18, contains the identification of several species collected by Major Hawn. Professor Swallow states: "I can have no doubt that the rocks are Permian, since the proof is very conclusive to my mind. . . . . All of the described fossils, with perhaps two exceptions, are identical with Permian species of Russia and England, while all of the new species appear to be more nearly allied to Permian forms than to any other." At the same meeting a portion of a paper by Professor Swallow and Major Hawn was read, entitled "The Rocks of Kansas, with descriptions of new fossils from the Permian formation in Kansas territory." The reading of this paper was concluded at the following meeting on March 8 (Trans. Acad. Sci. St. Louis, Vol. I., pp. 112, 113; and pp. 173–197). An abstract of the paper was read at the Baltimore meeting of the American Association for the Advancement of Science, May, 1858, and appeared in the Am. Journal of Science, November, 1858 (2d series, Vol. XXVI., pp. 182–188). Also published in Proc. Am. Assoc. Adv. Science, Vol. XII., 1859, pp.

Apparently the first published announcement of the Permian age of the Kansas fossils was a letter from Professor G. C. Swallow to Professor J. D. Dana, dated February 16, 1858, and printed in the March number of the *American Journal of Science and Arts*[1] Swallow mentioned some ten European Permian species; these or closely allied species he had identified in Major Hawn's collection and he stated "I can but feel that the above is sufficient to justify us in the decision that they are *Permian.*"

On March 2d, Professor James Hall read a paper by Meek and Hayden before the Albany Institute, describing a small collection of fossils "from near the mouth of the Smoky Hill fork of the Kansas River" concerning which is the statement: "We think there is scarcely room to doubt that it [the formation] is of Permian age."[2] A letter from Meek and Hayden making brief mention of the discovery was read the same day before the Philadelphia Academy of Natural Sciences.[3]

After reviewing the various statements referring to the discovery of Permian rocks and fossils in Kansas, it appears that to Professor Swallow belongs the credit of first announcing the fact before a scientific society and publishing a notice of the discovery in the leading scientific periodical of the country.[4]

214–221, where Professor Swallow says, "The Coal-measures occupy a belt along the eastern end of the territory, extending westward as far as Fort Riley. West of the Coal-measures the Permian strata are developed over a wide zone stretching across the territory from north to south" (p. 220).

[1] 2d series, Vol. XXV., p. 305*.

[2] Trans. Albany Inst., Vol. IV., p. 76. The paper is entitled "Descriptions of new organic remains from northeastern Kansas indicating the existence of Permian rocks in that territory," pp. 73–89. This paper was noticed in the May number of the Am. Jour. Sci. (2d series, Vol. XXV., p. 442).

[3] Proc. Acad. Nat. Sci., Philadelphia, Vol. X., pp. 9, 10.

[4] Professor Hayden stated that extras of the Albany Institute paper were distributed two days after it was read, so that the paper "was actually published on the 4th of March;" but he seems to have been in error in stating that the March number of the American Journal of Science, which contained Professor Swallow's letter, was issued "between the 4th and 10th of March" (Am. Jour. Science, 2d series, Vol. XLIV., 1867, p. 38, f. n.).

The Proceedings of the Albany Institute for March 2, 1858, following the remarks

TOPOGRAPHY.

The region under consideration is a belt of country varying in breadth from fifty to seventy-five miles, extending across the state from south to north in an approximate northerly direction. Topographically, it is a region with high hills which generally have rounded slopes capped by escarpments of massive limestone and flint. The valleys are narrow, and the landscape as a whole presents an appearance quite at variance with the preconceived idea of the plains of Kansas. As my knowledge of the country increases, I am led to see the resemblance that it bears, in miniature, to the Colorado plateau of the west [Utah and Arizona]. Its topographic features appear to be similar to the Ozark uplift of southern Missouri which has been well described by Nason as follows: "While at the base of these steep-sided hills we cannot escape the feeling that we are among mountains. A climb up the slope dispels the idea however. Instead of a commanding view from the summit of the divide we look forth upon what in the distance appears to be a plain stretching away on every hand. The mountain crests rise to the same level as far as the eye can reach."[1]

This elevated tract of land known as the "Flint Hills" crosses the southern boundary of the state on the line of Cowley and Chautauqua counties and then extends in a northerly direction with a breadth varying from twenty-five to forty miles. A view from the summit of the divides reveals an extensive plateau in which the streams have eroded many small valleys, leaving numerous mesas and other interesting topographic features due to the alternation of layers of flint and massive limestones with shales and shaly limestones. Along the valleys of the rivers and

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of Professor Hall upon Mr. Meek's paper, contain the following statement: "Mr. Gavit called attention to the fact that, in the last number of Silliman's Journal, Professor Swallow makes a similar announcement as to the identity of certain fossils of Nebraska with those recognized as Permian" (Trans. Albany Inst., Vol. IV., p. 248). Finally, Professor James D. Dana wrote me: "I have no doubt that the number for March, 1858, was out and off by the 1st [of March] if not before" (Letter of March 28, 1895).

[1] Geol. Surv. Missouri, Vol. II., 1892, p. 86.

larger streams and extending well up toward the heads of their branches are numerous trees; but on the upland of the plateau nothing appears save the native prairie grass. At numerous points are extensive views of most interesting landscapes which are especially beautiful when clothed with the bright green grass of early summer.[1]

As the summer advances the grass is frequently turned brown by the hot, dry weather so that during August and September the ground is parched and barren, and it is not at all strange that the early explorers of Kansas described the region as a "desert." Professor Broadhead has called attention to some of the interesting topographic features of this region and has suggested that it "might appropriately be termed the Permian Mountains."[2] In a recent paper Professor Haworth has admirably described the topographic features of eastern Kansas, and concisely stated that its terraced topography is due to "a condition which seems dependent principally upon the more or less regular occurrence of alternating heavy beds of soft shales with light beds of harder limestones and sandstones."[3] The professor also speaks of the beauty of the scenery[4] along the Kansas River and the "magnificent bluffs"[5] which line the upper part of its valley.

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[1] Among other places the writer would especially mention Blue Mount at Manhattan, looking up the canyon of the Kansas River, which presents a scene of surpassing beauty. Fine views may also be obtained at various places on the southern side of the Kansas River between Manhattan and Junction City; at numerous places in Wabaunsee county south of Alma and southeast toward Eskridge; in Chase county southwest of Cottonwood Falls, on the southeastern side of Cottonwood River, and in the southern part of the state in the eastern portion of Cowley and western portion of Chautauqua county.

[2] Trans. St. Louis Acad. Science, Vol. IV., Pt. III., 1883 (?), p. 484. Again, on page 491, occurs this statement: "The group of the Permian Mountains forms an interesting study, the strata are easily traced, and the scenery afforded is very fine and the views very extensive." An abstract of this paper was published in the Am. Jour. Science, 3d series, Vol. XXII., 1881, pp. 55–57, and the above quotations appear on pp. 55 and 57 respectively.

[3] Kansas Univ. Quarterly, Vol. II., 1894, p. 134.

[4] *Ibid.*, p. 131.

[5] *Ibid.*, p. 134.

Principal rivers.—Two river systems have cut approximately east and west valleys through this plateau, nearly at right angles to the trend of its flint ridges. The Smoky Hill and Kansas Rivers have cut the valley in the northern part of this range, while the Cottonwood River has eroded a similar valley through its central part. The great value of these two valleys in determining the character and stratigraphic relations of the geologic formations composing the upper Palæozoic and lower Mesozoic rocks of Kansas was early appreciated, consequently these two great sections are classics in the literature of the Permian and Permo-Carboniferous rocks of Kansas. In a recent article the writer has discussed the geology of the Kansas River section, particularly from Manhattan to Junction City; identified and correlated as far as possible the various beds of that section as described by Meek and Hayden, Swallow, and Hay, and given lists of fossils which characterize the various divisions of the section.[1] The present paper proposes to consider in a similar manner the classic section of the Cottonwood Valley and in addition, to define briefly the formations into which the writer has divided the upper Palæozoic rocks of Kansas.

The Cottonwood River valley.—About seven miles below the city of Emporia, the Cottonwood River enters the Neosho and reaches the Arkansas River near Fort Gibson in the Indian Territory; consequently the Cottonwood River forms a part of the great drainage system of the Arkansas. For more than twenty miles from its mouth, to a point near Ellinor, the Cottonwood River flows through a broad, fertile valley with low hills in the distance. But above Ellinor it rapidly narrows, except where tributary streams enter it, to a valley one or two miles in width, lined on both sides with steep hills which are generally capped by a prominent escarpment of massive limestone or flint. This type of valley continues westerly as far as the junction of the South Cottonwood River with the Cottonwood, two miles west of Marion; and for some forty miles along the main line of the

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[1] Kansas River section of the Permo-Carboniferous and Permian Rocks of Kansas, Bull. Geol. Soc. America, Vol. VI., pp. 29–54.

Atchison, Topeka & Santa Fé Railroad from Ellinor to a point near Peabody. The bluffs on the southern side of the river are generally higher and more continuous than those on the northern side. This is well shown in the bluff extending from the vicinity of Cottonwood Falls southwest to Florence, where for a distance of twenty-three miles there are but two decided breaks, one of which occurs at Clements formed by Coyne Branch, and the other at Cedar Point where Cedar Creek enters the Cottonwood. From the northern side of the valley different prominent strata of limestone are seen forming terraces near the summit of the bluff. This is especially noticeable along the bluff from Cedar Point to the summit opposite Florence. A similar bluff, but higher and steeper, extends for twenty miles along the south side of the Kansas River, from Manhattan to Junction City, broken only by the two valleys formed by McDowell and Clark Creeks. As far as my observation goes, the southern bank of many of the streams in this part of Kansas is steeper than the northern, and Professor Haworth tells me that such a statement applies in a general way to all the rivers of Kansas.

DESCRIPTION OF THE GEOLOGICAL FORMATIONS.—THE WABAUNSEE FORMATION.

In the classification of the rocks into formations, primarily for use in areal geology, it has been the general intention to include in a formation a series of strata, which may be characterized by their fossils and which have similar lithologic characters.

In the lower valley of the Cottonwood, as well as along the adjacent portion of the Neosho, are several rather massive beds of limestone between which are calcareous, argillaceous and arenaceous shales with an occasional thin stratum of coal. The limestones of this formation cap the low bluffs along the river valley to Ellinor, where a higher limestone, known as the Cottonwood, appears near the top of the bluff, which, dipping westerly, is carried nearly down to the level of the river about one and one-half miles west of Strong City; then begins to rise again until it reaches the top of the high bluff 200 feet above the river at Elmdale. As a result of this folding the Wabaunsee formation extends thirteen miles farther up the Cottonwood River to the vicinity of Clements.

This series of limestones and shales is well exposed along the Neosho River below and above Emporia, and especially to the north, in the eastern and northern portions of Wabaunsee county. There are excellent outcrops in the bluffs along Allen, One Hundren and Forty-Two Mile, and Elm Creeks in the northern part of Lyon county; on Elk, Dragoon and Mission Creeks in southern and eastern Wabaunsee county, and particularly on Mill Creek in the northern part of the county; and on the bluffs of the Kansas River from Wabaunsee to the vicinity of Ogden in Riley county. I have considered the base of this formation as defined by the top of the Osage coal horizon,[1] and the top by the base of the massive limestone known locally as the Cottonwood, Alma and Manhattan limestones. Mr. Charles R. Keyes has proposed the name Missouri formation for the upper Coal Measures of Iowa and Missouri,[2] but did not clearly indicate the upper limit of the formation. The deposits forming the upper coal measures of Kansas are principally of the same age as those in northwestern Missouri, and, if we consider the Osage and Silver Lake coal horizon as the upper limit of the Missouri formation in Kansas, then the Wabaunsee formation will directly succeed the Missouri formation. The formation covers one-half of Wabaunsee county and, on account of the excellent exposures along nearly every stream in the eastern and northern portions of the county, I would propose that it be called the *Wabaunsee formation.*

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[1] This is near the line of division between the upper Carboniferous and Coal Measures of Professor Mudge. The Professor states that the dividing line between these formations "is not clearly defined or easily fixed . . . . . Plants and coal are the best evidences, and even these are not strongly marked" (First Bien. Rept. [Kans.] State Board Agri., p. 71, and see p. 86 for place of the Osage coal). Professor Mudge, however, did not understand the northern and southern extent of this horizon, as was shown later by Professor St. John (Third Bien. Rept. [Kans.] State Board Agri., p. 585) and Hay (Eight *ibid.*, p. 132). Finally Professor Haworth has shown that on the Kansas River the Silver Lake Coal, 125 feet above the Topeka, is the equivalent of the Osage Coal (Kan. Univ. Quart., Vol. III., pp. 304, 305 and Plate XX).

[2] Iowa Geol. Surv., Vol. I, 1893, p. 114. *Ibid.*, Vol. II, 1894, Plate III, and p. 137. Missouri Geol. Surv., Vol. IV, Pal. Mo., Pt. I, 1894, p. 82.

Early geologic explorations.—The rocks of this formation along the Kansas River, especially from Mill Creek westward, were carefully examined by Meek and Hayden in the summer of 1858, and a paper describing the geology of the region traversed appeared the following January.[1] During the same summer Dr. Newberry studied this series of rocks as exposed along the Santa Fé road, on his return from the Ives exploring expedition of the Colorado River of the West, from Santa Fé to Fort Leavenworth, crossing the Neosho River at Council Grove.[2]

In the summer of 1859 Dr. Newberry again crossed the same formations as exposed along the route from Independence, Mo., to Santa Fé on his way to join the Macomb exploring expedition and described to some extent the rocks and fossils found along Dragoon Creek and on the high ground to the west.[3]

Palæontology.—The calcareous and argillaceous shales frequently contain numerous specimens of fossils representing a considerable number of species; but in the massive limestones the number of species and individuals is usually smaller.

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[1] Proc. Acad. Nat. Science, Philadelphia, Vol. XI., p. 8; see particularly pp. 14 and 18. A part of this paper including the "general section of the rocks of Kansas valley" appeared in the Am. Jour. Sci., May, 1859 (2d series, Vol. XXVII., pp. 424–432).

[2] Dr. Newberrys's observations on this trip were published in 1861 in the Report upon the Colorado River of the West, explored in 1857 and 1858 by Lieut. Joseph C. Ives. Geological Report by Dr. J. S. Newberry, Chapter X., Geology of the route from Santa Fé to Fort Leavenworth, p. 102. See particularly pp. 110–115. Meek and Hayden's "General section of the rocks of the Kansas Valley" from Manhattan to the Cretaceous is copied on pp. 112–114.

[3] Report of the Exploring Expedition from Santa Fé, New Mexico, to the junction of the Grand and Green Rivers of the great Colorado of the West in 1859, under the command of Capt. J. N. Macomb, with Geological Report by Professor J. S. Newberry. See Chapter I., and especially pp. 16–21. Although Dr. Newberry's report was finished in 1860, it was not published until 1876, but in his Prefatory Note of June, 1875, we find these words: "Precisely as written in 1860." A brief account of this trip appeared in the September number of the Am. Jour. Science, for 1859 (2d series, Vol. XXVIII., pp. 298, 299) where Dr. Newberry states that "from Wellington to Cottonwood and Turkey Creek the Permian was constantly found in the hill-tops, but the valleys were excavated down to the Carboniferous" (p. 298).

From the exposures of shales and limestones on Mill Creek, the following species were obtained, which are arranged in the order of their relative abundance and may be considered the characteristic fossils of the formation:

1. *Chonetes granulifera*, Owen.
2. *Productus* (*Marginifera*) *splendens*, Norw. and Pratt.
3. *Productus semireticulatus*, (Martin) de Koninck.
4. *Productus cora*, d'Orbigny.
5. *Spirifer* (*Martinia*) *planoconvexus*, Shum.
6. *Fusulina cylindrica*, Fischer.
7. *Athyris* (*Seminula*) *subtilita*, (Hall) Newb. = *A. argentea*, (Shep.) Keyes.
8. *Pugnax uta*, *Marcou* (Marcou) Hall and Clarke.
9. *Productus nebrascensis*, Owen.
10. *Hustedia mormonii*, (Marcou) H. and C.
11. *Septopora biserialis*, (Swallow) Waagen.
12. *Rhombopora lepidodendroides*, Meek.
13. *Spirifer cameratus*, Morton.
14. *Pinna peracuta*, Shum.
15. *Phillipsia scitula*, Meek and Worthen.
16. *Derbya crassa*, (Meek and Hayden) H. and C.
17. *Meekella striato-costata*, (Cox) White and St. John.
18. *Chonetes Flemingi*, (according to Keyes) Norw. and Pratt.
19. *Allorisma Geinitzii*, Meek (?)
20. *Campophyllum torquium*, (Owen) Meek?
21. *Chonetes glabra*, Geinitz = *C. lævis*, Keyes.
22. *Productus symmetricus*, McChesney.
23. *Spiriferina kentuckensis*, Shum.
24. *Enteletes hemiplicatus*, (Hall) H. and C.
25. *Dielasma bovidens*, (Morton) H. and C.
26. *Orbiculoidea nitida*, (Phillips) H. and C.
27. *Myalina subquadrata*, Shum.
28. *Allorisma subcuneatum*, M. and H.
29. *Aviculopecten occidentalis*, (Shum.) Meek and Worth.

30. *Straparollus* (*Euomphalus*) *subrugosus*, Meek and Worth. = *S. catilloides*, (Con.) Keyes.

The bluffs along the Kansas River near Manhattan afforded me the following additional species:

31. *Fistulipora nodulifera*, Meek.
32 *Fusulina cylindrica*, Fischer, var. *ventricosa*, M. and H.
33. *Lingula umbonata*, Cox.
34. *Orbiculoidea manhattanensis*, (M. and H.) H. and C.
35. *Nuculana bellistriata*, Stevens, var. *attenuata*, Meek. (?)
36. *Dawsonella Meeki*, Bradley (?)
37. *Lophophyllum proliferum*, (McChes.) Meek
38. *Cladodus mortifer*, Newberry and Worthen.

In the lower part of the formation, from exposures along the Kansas River below the mouth of Mill Creek and extending to the vicinity of Topeka, the following additional species were obtained:

39. *Bellerophon sublævis*, Hall.
40. *Myalina Swallovi*, McChesney.
41. *Allorisma* (*Sedgwickia*) *topekænsis* (Shum.) Meek.
42. *Myalina perattenuata*, M. and H.
43. *Productus punctatus* (Mart.) Sowb.
44. *Allorisma* (*Sedgwickia*) *Geinitzii*, Meek.
45. *Edmondia ovata*, Meek.
46. *Schizodus curtus*, M. and W.
47. *Nuculana bellistriata* (Stevens) Meek.
48. *Allorisma granosa* (Shum.) Meek.
49. *Macrodon tenuistriata*, M. and W.
50. *Modiola* (?) *subelliptica*, Meek.
51. *Productus pertenuis*, Meek.
52. *Edmondia aspinwallensis*, Meek.
53. *Entolium aviculatum* (Swallow) Meek.
54. *Solenomya radiata*, Meek and Worth.

As will be seen from the above fauna this formation clearly belongs in the upper part of the Carboniferous to which system these rocks have generally been referred.

Meek and Hayden's classification.—In Meek and Hayden's paper of 1859 it was proposed to divide the upper Palæozoic rocks into the Permian and Permo-Carboniferous.[1] They did not indicate precisely this line of separation, but it seems probable that their Permo-Carboniferous division included the upper part of the Wabaunsee formation.[2]

Newberry's classification.—It is evident that Dr. Newberry in his early explorations regarded the rocks of this formation as belonging to the Carboniferous, for he stated in 1860 that "at Dragoon Creek [probably on the Santa Fé trail in the southeastern part of Wabaunsee county where the upper part of the course of Dragoon Creek is eroded in rocks belonging to the Wabaunsee formation, while the upper part of the bluffs belong to the overlying formation] we reach the extreme summit of the Carboniferous formation, and first meet with those which may be regarded as distinctly Permian."[3]

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[1] Also see the following statement of Meek and Hayden: "We are inclined to the opinion that the entire series, from near the top of the Lower Permian of Professor Swallow's and Mr. Hawn's section, down even lower than the horizon where they draw the line between the coal measures and the lower Permian, should be regarded as intermediate in age, and as filling the hiatus between the Permian and upper coal measures of the Old World. . . . This intermediate series might be very appropriately termed the Permo-Carboniferous group, to indicate its relations both to the Permian and Carboniferous rocks" (Am. Jour. Science 2d series, Vol. XXVII., January 1859, p. 35).

[2] See PROSSER: Bull. Geol. Soc. Amer., Vol. VI., p. 51, and notice the line of separation indicated with a question on p. 53. The authority for this statement may be found in Hayden's article in the Amer. Jour. Science, 2d series, Vol. XLIV., 1867, p. 37, where he states that "Meek and Hayden regarded the beds . . . . down so far as to include most, if not nearly all, of Professor Swallow's Lower Permian, as an intermediate connecting series between the Permian and Coal Measures, which, if worthy of a distinct name at all from the latter, should be called Permo-Carboniferous."

[3] Rept. Explor. Exp. 1859, Macomb, p. 19. It is not clear from the context whether by "Permian," Dr. Newberry meant the base of the Permo-Carboniferous, or the base of what he called "true Permian;" but the former seems to have been his interpretation, for on p. 16, in enumerating localities containing numerous fossils, he mentions "Permo-Carboniferous at Dragoon Creek and Wilmington" [name of southeastern township of Wabaunsee county, with town of same name in the southeastern corner on Soldier Creek] and "true Permian on the hill-tops east of Council Grove [which would be some twenty miles southwest of the Permo-Carboniferous localities], and on Cottonwood Creek." Also in describing the region toward Council Grove is the statement that "over a considerable area in this vicinity the highlands are occupied by what may be considered true Permian strata, while the valleys of all the water-courses are exca-

At this time Dr. Newberry clearly recognized the difficulty of separating the Carboniferous and Permian systems by any sharp line, and he said, "From this interlocking of the Carboniferous and Permian faunæ, it is evident that the line of separation between the two formations must continue to be debatable ground; and as there is, in fact, a group which contains a mingled fauna—in truth, a Permo-Carboniferous group—we must introduce this new member into the geological series, or fix upon some conventional line which shall form the boundary between the summit of the Carboniferous and the base of the Permian formations."[1]

Comparison of the Wabaunsee formation with Swallow's section.—Professor Swallow in his Preliminary Report on the Geology of Kansas divided the rocks of eastern Kansas into 256 beds which were referred to the Quarternary, Tertiary, Cretaceous, Triassic, Permian and Carboniferous systems.[2] In his section the rocks which we have referred to the Wabaunsee formation were described from exposures occurring principally along the Kansas River, Mill Creek and adjacent country. As the limits of the Wabaunsee formation have been indicated, it includes the rocks from the top of Swallow's bed, No. 154, up to the base of bed, No. 80. The greater part of the formation belongs to the upper part of the Carboniferous system of Swallow, which he called "Formation *a*—Coal Measures," including the larger portion of his "Stanton Limestone series" and all of the following series in ascending order, "Chocolate Limestone" and "Upper Coal series." In addition to the above rocks the Wabaunsee formation includes the four beds forming the base of Swallow's "Lower

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vated to and into the Permo-Carboniferous, or, as I have called them, Upper Carboniferous strata" (p. 20). Again he says, "the Permian magnesian limestones occupy the general surface, but are cut through by the valleys of the draining streams. Below them are exposed strata containing *Orthisina umbraculum; Productus Calhounianus;* spines of a species of *Archæocidaris*, regarded by Professor Swallow as identical with *A. Verneuiliana*, King; a small *Athyris*, and a *Rhynchonella:* all of which belong rather to the Carboniferous than to the Permian fauna" (p. 21).

[1] *Ibid.*, p. 20.

[2] Prel. Report, Geol. Survey, Kansas, 1866, section of the rocks in eastern Kansas, pp. 9–29.

Permian," Nos. 84–80, to which he assigned a thickness of forty-two feet, and claimed that on Mill Creek the base of the Lower Permian was separated from the Carboniferous by unconformability.[1] In general it is not difficult to identify the beds which Swallow referred to the Permian, but those of the Carboniferous are not as clearly defined. Swallow gives the total thickness of the beds which I have included in the Wabaunsee formation as 546 feet, while from my estimate of the exposures along the Kansas River the formation has a thickness of probably 575 feet.

As stated above, the greater part of this formation consists of a series of limestones alternating with argillaceous and calcareous shales which it is not necessary to consider in detail in this article. The upper part of the Wabaunsee formation is more important in reference to the geological classification of these rocks, since the line drawn by Professor Swallow separating the Carboniferous from the Permian occurs forty-two feet below its top. Professor Swallow considered bed, No. 84, of his section, which he named the "dry bone limestone," the base of his Lower Permian; next above came bed No. 83, composed of "bluish-brown marls, one foot;" then No. 82, the "Cotton rock, five feet," above which was No. 81, composed of thirty-one feet of shales and marls which is the top of the Wabaunsee formation. These shales are capped by a massive limestone, six feet thick, called bed No. 80 by Swallow and named the "*Fusulina* limestone" on account of the abundance of this fossil. Professor Swallow states that beds "Nos. 82, 83 and 84, are sometimes represented by a bluish-gray and buff porous magnesian limestone, ... containing numerous Permian *Acephala* and *Zaphrentis* and small *Spirifer*," and he gives the locality as the Cottonwood.[2]

This limestone is in general very prominent in the bluffs along the Cottonwood River from the vicinity of Ellinor to within three miles of Clements. A mile west of Strong City it is carried below the surface by a synclinal fold, but it reappears west of Simmons Creek three miles west of Strong City, where it forms a prominent ledge on the northern side of the valley which is conspicuous from the Atchison, Topeka & Santa Fé trains. It also forms a prominent ledge on the southeastern bank of the river below and above Elmdale, as well as on the northwestern side, some distance from the river until within four miles of Clements, where it becomes more conspicuous on the Blackshere ranch (Sec. 12, 20 S., 6 E.). This ledge, a massive bluish-gray stratum in places seven feet or more in thickness, frequently breaks on the edges into large blocks, with sharp angles and rough, jagged surface, which usually weather to a color not dissimilar to that of bleached bones, hence the name "dry bone limestone" is not especially inappropriate. Professor Swallow repeatedly stated that the limestones all through the rocks which he called Permian were strongly magnesian and regarded their chemical composition as an important character in separating the Carboniferous and Permian systems. The professor was in error in this particular and must have considered the limestones to be magnesian from their general appearance since a chemical analysis of them fails to reveal magnesia in any considerable amount.[1] This erroneous view in reference to their chemical composition was noticed by Professor Mudge,[2] and the error is very evident from an examination of the table of

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[1] See section on p. 16, and the following statement on p. 44: "Nos. 85–95, from the sections near Manhattan are not found in the Mill Creek sections, where No. 84 rests directly upon the Fusulina shales, No. 96."

[2] *Ibid.*, p. 16.

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[1] This is well shown by the following analysis of a specimen of the "dry bone limestone" from Manhattan, by Mr. Warren Finney, who kindly analyzed a series of these limestones for me :

SiO_2	2.34 per cent.
Fe_2O_5	0.03 "
$CaCO_3$	97.46 "
$MgCO_3$	1.02 "
Al_2O_3	trace
	100.85 "
CO_2	44.34 "

[2] First Bien. Rep. [Kansas] State Board Agri., 1878, Geology of Kansas, p. 70, where in describing the Permian and Upper Carboniferous he said, "Some of the lime has been called magnesian, but analysis has failed to show, in more than a single

"Analyses of Kansas building stones" prepared by Dr. S. W. Williston for the Columbian Exposition.[1]

Professor Swallow claimed that the main reason for drawing the line of separation between the Carboniferous and Permian at the base of the "dry bone limestone" was the fact "that the Permian fossils come down in force to this line and but few go below, while a few species only of Carboniferous fossils are found above it."[2] In beds, Nos. 82, 83 and 84, I have found but few fossils and those are not especially Permian types, while it will be shown that in the Cottonwood shales of the succeeding formation there are abundant specimens of characteristic Carboniferous species. The small *Spirifer* mentioned by Professor Swallow in this limestone on the Cottonwood[3] is *S. cameratus*, Morton which I have not found at a higher horizon.

Comparison with Haworth and Kirk.—In the paper describing the Neosho and Cottonwood River sections by Professor Haworth and Mr. Kirk, this limestone is called No. 12, and its extent is well shown along the Neosho River from five miles above Emporia to Dunlap. It is also accurately noted on the Cottonwood from the vicinity of Ellinor to Strong City, but it was not recognized on its reappearance three miles farther west.[4]

THE COTTONWOOD FORMATION.

Succeeding the Wabaunsee formation is a massive yellowish to light gray limestone with a maximum thickness of six feet capped by yellowish calcareous shales fourteen feet thick which together have been called the Cottonwood formation.[5]

Geologic section of the Cottonwood formation.—The thickness of the formation is about twenty feet, and it is well exposed in the

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instance, over 5 per cent. of magnesia." This statement is not correct for the limestones of the Permian, but well expresses the chemical composition of the lower limestones.

[1] Mineral Resources, U. S., for 1893, pp. 563–565.

[2] Prel. Rep. Geol. Surv., Kansas, p. 44.

[3] *Ibid.*, p. 16.

[4] Kan. Univ. Quart., Vol. II., pp. 112, 113 and Pl. IV., Figs. 2 and 3.

[5] PROSSER: Bull. Geol. Soc., Amer., Vol. VI., p. 40.

Fox Creek quarry and bluff, one mile west of Strong City. At this locality there is the following section:

No. 4. Blocky limestones from 1′ 6″ to 2′ in thickness separated by shaly partings. This bed is referred to the succeeding formation (Neosho).

No. 3. Yellowish, calcareous shales which contain plenty of calcite (?) nodules but no fossils. Between 6′ and 7′.

No. 2. Similar shales containing plenty of fossils which in the lower part are extremely abundant. 7′ 2″.

No. 1. Massive limestone. Stratum not fully exposed. 4′ 8″ +.

Distribution and character of the Cottonwood limestone.—Along the bluffs of the Cottonwood River this limestone first appears as a prominent ledge near Ellinor and on account of folding may be followed up the Cottonwood River to Crawfordsville or Clements. It may be traced along the principal branches of the Cottonwood River as follows: Up the South Fork to three miles south of Bazaar; along Middle Creek for eight miles; and up Diamond Creek to Hymer. It is the most valuable dimension stone in the state and at various places are extensive quarries which afford an excellent opportunity to study the limestone and its overlying shales. Some of the more important quarries are those on the north side of the river between two and three miles east of Strong City; the Lantry & Sons' quarry in the city limits, and the Fox Creek quarry one mile west of Strong City. On the south side are those of the Rettiger Bros., Du Chanois and Jones two and one-half miles east of Cottonwood Falls, and the Perrin quarry in Cottonwood Falls, while farther up the river near Clements are the quarries of D. Y. Hamill. The limestone on a fresh fracture is yellowish-gray in color weathering to a light gray and generally appears along the side of the moderately steep bluffs as a series of rectangular blocks that have been separated from the main ledge. The stone is very strongly calcareous containing about 85 per cent. of calcium carbonate and less than 2 per cent. of magnesian carbonate.[1]

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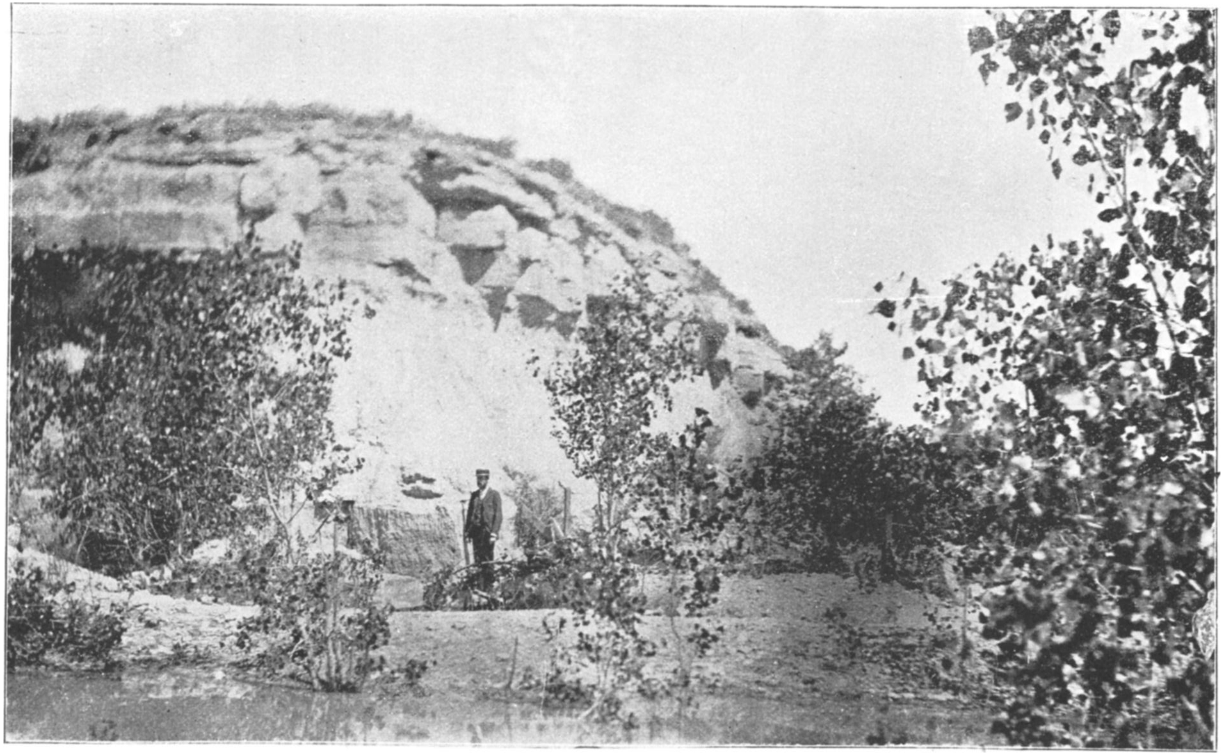
[1] Dr. S. W. Williston reports the following analysis:

Insoluble matter - - -	8.57 per cent.
Oxides of iron and alumina - -	3.62 "
Calcium carbonate - - -	84.72 "



No. 1. View of the Cottonwood limestone and shales capped by the blocky limestones at the base of the Neosho formation. Fox Creek quarry west of Strong City.

The amount of flint contained in the rock varies. In some localities it is scarcely perceptible while in others the quantity is sufficient to make the rock comparatively valueless for economic purposes. There are very few fossils, with the exception of *Fusulina cylindrica*, Fischer, which is extremely abundant in the upper part of the stratum. The quarrymen call these fossils grains of wild rice, and on account of their great abundance Professor Swallow called the stratum the "*Fusulina* limestone."[1] This limestone forms one of the most important features in the stratigraphy of the Upper Palæozoic rocks of Kansas and in many respects is as valuable for stratigraphic purposes as the Tully or Corniferous limestones in the Devonian of New York.

Fauna of the Cottonwood shales.—The yellowish overlying shales, which may be called the Cottonwood shales, constitute one of the most fossiliferous horizons of the Carboniferous, although there are but a few species that are extremely abundant. The immense number of fossils in this shale was noted by Professor Haworth and Mr. Kirk, who stated that in the shale of the Rettiger quarries "marine invertebrate fossils are unusually abundant,"[2] but in general this, its most striking characteristic wherever exposed, seems to have been overlooked.[3]

Wherever the shale has been exposed for some time to the action of the atmosphere large numbers of loose fossils perfectly

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Magnesian carbonate - - -	1.75	"
Sulphates - - - - -	.90	"
	99.56	"

Mineral Res., U. S. for 1893, p. 563. The samples came from the Rettiger Bros.' quarry, the crushing strength being 6800 lbs.; weight per cubic foot 161.6 lbs.; and the specific gravity 2.59.

[1] Prel. Rep. Geol. Surv. Kans., p. 16.

[2] Kans. Univ. Quart., Vol. II., p. 113.

[3] Professor Broadhead probably noticed the fossils of this shale, but his reference is quite indefinite. The Professor mentions quarries in the Cottonwood Valley containing "about six feet of very good building stone," probably the Cottonwood limestone, and says, "the associated shale beds abound in fine fossils, including *Prod. semireticulatus; Hemp. crenistria;* a large variety of *Chonetes granulifera* and *Athyris subtilita, Archæocidaris*, and a Crinoid" (Trans. St. Louis Acad. Sci., Vol. IV., Pt. III., p. 492).

preserved may be found. This is especially true of *Chonetes granulifera*, Owen, which in places may be collected by the hundreds from the top of the underlying limestone, or in the soil formed by the decomposed shale.

In the Cottonwood shales at the Rettiger Bros.' quarry the following species were collected:

1. *Chonetes granulifera*, Owen. (aa)[1]
2. *Derbya crassa*, (M. and H.) Hall and Clarke. (a)
3. *Athyris* (*Seminula*) *subtilita*, (Hall) Newb. = *A. argentea*, (Shep.) Keyes. (a)
4. *Productus semireticulatus*, (Martin) de Koninck. (a)
5. *Meekella striato-costata*, (Cox) White and St. John. (c)
6. *Productus nebrascensis*, Owen. (r)
7. *Aviculopecten McCoyi*, M. and H. (r)

   Imperfectly preserved specimens which seem to agree closely with this species. There are heavy costæ which show the base of spines and these ribs are separated by two or three smaller plications.
8. *Straparollus* (*Euomphalus*) *subrugosus*, Meek and Worth. = *catilloides*, (Con.) Keyes. (rr)
9. *Septopora biserialis*, (Swallow) Waagen. (rr)
10. *Rhombopora lepidodendroides*, Meek. (rr)
11. *Lophophyllum proliferum*, McChesney. (rr)
12. *Fusulina cylindrica*, Fischer. (rr)
13. *Aviculopecten occidentalis*, (Shum.) M. and W. (rr)
14. *Dielasma bovidens*, (Morton) H. and C. (rr.)
15. *Chætetes* cf. *carbonarius*, Worth. (rr)

    In addition to the above list the following species were obtained from exposures of the Cottonwood shales near Cottonwood Falls or Strong City:
16. *Phillipsia scitula*, M. and W. (?) (rr)
17. *Crinoid* plates and stem.
18. Fish plate.

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[1] The relative abundance of the species is indicated in the following manner: a=abundant; aa=very abundant; c=common; r=rare; rr=very rare, when but one or two specimens are found.

19. *Archæocidaris* plates and spine.
20. *Bryozoa* sp.
21. *Glauconome* sp.

From the Hamill quarry near Clements the two following species were obtained:

22. *Productus cora*, d'Orbigny. (rr)
23. *Fistulipora nodulifera*, Meek. (rr)

A study of the above fauna will clearly show it to be one of the Upper Carboniferous of the Mississippi Valley and Great Plains, although many of the species occur in the deposits called Permo-Carboniferous and an occasional one has been reported from the so-called Permian rocks of the United States. A comparison of the fauna of the Wabaunsee formation with that of the Cottonwood will reveal the fact that while the former contains more than twice as many species as the latter, which proportion will probably not be materially changed by further search, still every species of the Cottonwood formation with the exception of *Aviculopecten McCoyi*, M. and H., and *Chætetes* cf. *carbonarius*, Worth, which are doubtfully identified, occurs in the Wabaunsee formation, consequently, as far as the biologic evidence is concerned, there is no support for placing the Cottonwood formation in a system or even series, distinct from that of the Wabaunsee.

Former descriptions of the Cottonwood limestone.—The Cottonwood limestone was among the first stones of the state to be used for construction where strength and durability were desired, but it is not known to the writer at what date it was first called the "Cottonwood stone." It forms bed No. 80 of Swallow, which he called the "*Fusulina* limestone" and described as "buff, porous and magnesian," six feet thick, exposed at "Manhattan, Cottonwood Falls and Mill Creek."[1]

It forms the summit of Blue Mount and Mount Prospect at Manhattan and the bluffs along Mill Creek above Alma, consequently it appears that Professor Swallow correlated the several exposures of this limestone correctly although he made no reference to its extent, in the descriptive part of the work. Later

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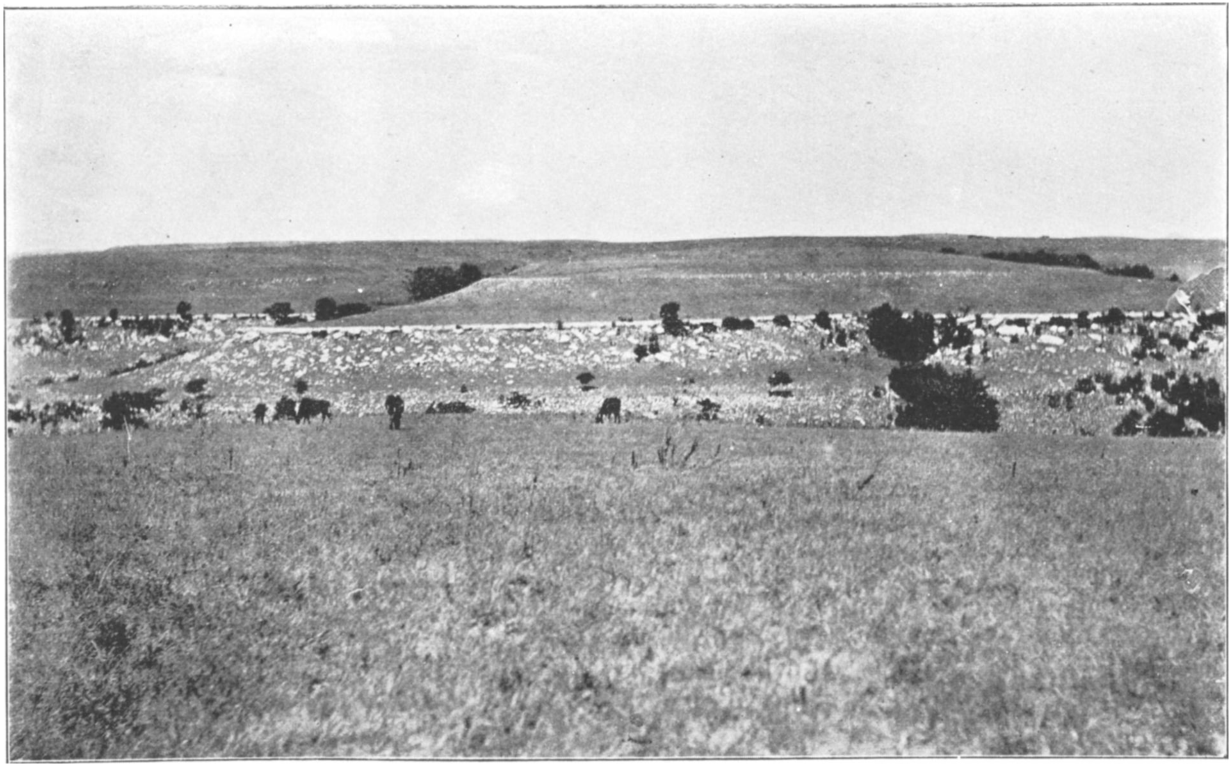
[1] Prel. Rept. Geol. Surv. Kansas, 1866, p. 16.



No. 2. Line of the Cottonwood limestone on the north side of the Kansas River west of Manhattan. Characteristic appearance of the limestone along the bluffs of streams.

writers seem to have overlooked his conclusions and there has been much confusion concerning the correlation of the prominent limestones of the Kansas and Cottonwood valleys. Professor St. John referred to the extensive quarries near Strong City, where he stated "the ledge is extensively wrought."[1]

Professor Haworth and Mr. Kirk described briefly the Cottonwood limestone as it occurs on the Neosho River from Dunlap toward Council Grove and on the Cottonwood River near Cottonwood Falls, and called it Limestone System No. 13 "of their section."[2]

Geographic extent of the Cottonwood limestone.—In general it seems that the stratigraphic importance of the Cottonwood formation has been overlooked. The constant character of the limestone, its line of outcrop frequently marked by a row of massive, light gray rectangular blocks filled with *Fusulina cylindrica* and capped by a yellowish shale in which occur immense numbers of *Chonetes granulifera*, *Athyris subtilita*, *Productus semireticulatus* and a few other fossils constitutes one of the most distinctive formations yet seen in the upper Palæozoic rocks of Kansas, and is very valuable for the purposes of stratigraphic and areal geology. Recently there have been general statements in reference to its extent across the state,[3] and such distribution is very probable; although I believe it has actually been traced but part of the distance. In the summer of 1894 the writer traced this formation from the northern part of Greenwood county into Riley county north of the Kansas River. There are good exposures of the limestone in the eastern part of Chase county on the South Fork of the Cottonwood River and its eastern branches. It may be traced up the Cottonwood River to Clements; from Strong City to the vicinity of Ellinor, then across the divide into the Neosho valley near Dunlap, when it follows the bluffs of the river about half the distance to Council Grove, then turns northeasterly across the high land of Wabaunsee county, passing near Bushong and the heads of the various streams in eastern Wabaunsee to Eskridge at the head of Dragoon Creek. From Eskridge it continues north on the high land near the head of Mission Creek, reaching Mill Creek near Alma. It continues northerly across the divide toward Wabaunsee, then follows the high bluffs along the south side of the Kansas River to Manhattan and extends up the river valley to the vicinity of Ogden, about five miles below Fort Riley. Along the entire extent of this line which is about one half the distance across the state, the formation is clearly marked wherever there are exposures, and its distinctive characters are very constant.[1]

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[1] Third Bien. Rep. [Kansas] State Board Agri., Vol. VIII., 1883, p. 584.

[2] Kans. Univ. Quart., Vol. II., pp. 112, 113, Pl. IV., Figs. 2 and 3. Also, see *ibid.*, Vol. III., p. 279.

[3] A pamphlet on the "Mineral Resources of Kansas," prepared for the Columbian Exposition, speaks of the Cottonwood Falls limestone as "the most extensive limestone bed in the state, and can be traced as one continuous formation across the state from north to south" (p. 18). The author, however, did not know the stratigraphic relations of the Cottonwood limestone, for he considered as one and the same the limestone at Manhattan in the Kansas valley and that at Florence in the Cottonwood valley, while as a matter of fact that at Florence is entirely different in character and is stratigraphically 250′ above the Cottonwood limestone. The "Report of the Kansas Board of World's Fair Managers, 1893," describes a limestone, which, from the localities mentioned (Manhattan, Alma, Strong City, etc.) is evidently the Cottonwood stone, that forms a "horizon which is traceable across the state from east of Marysville [Beattie, Marshall Co.], on the north, to Cambridge, Cowley county, on the south."

CHARLES S. PROSSER.

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[1] The author first called attention to the important stratigraphic character of this formation and briefly outlined its course across eastern central Kansas in 1894 (see Bull. Geol. Soc. Amer., Vol. VI., p. 40, and particularly footnote ‡). Later Professor Haworth has indicated in a general way the outcrop of the Cottonwood Falls limestone across the state (Kans. Univ. Quart., Vol. III., April, 1895, Pl. XXI. and p. 279).

[To be continued.]